UNIVERSITY OF ALBERTA

ECOLOGICAL RESPONSES TO CHEMICAL FENCING: MANAGING WATERFOWL NESTING HABITAT WITH A GRAZING REPELLENT

BY

TERRANCE JAMES OSKO

A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

WILDLIFE AND RANGELAND RESOURCES

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

SPRING 1993

ISBN 0-315-82141-8

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: **TERRANCE JAMES OSKO**

TITLE OF THESIS: **ECOLOGICAL RESPONSES TO CHEMICAL FENCING: MANAGING WATERFOWL NESTING HABITAT WITH A GRAZING REPELLENT**

DEGREE: **MASTER OF SCIENCE**

YEAR THIS DEGREE GRANTED: **SPRING 1993**

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DATE: 22 April 1993

"One swallow does not make a summer,

but one skein of geese, cleaving the murk of a March thaw,

is the spring."

Aldo Leopold (1887 - 1948)

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Ecological Responses to Chemical Fencing: Managing Waterfowl Nesting Habitat With a Grazing Repellent** submitted by **Terrance James Osko** in partial fulfillment of the requirements for the degree of **Master of Science** in **Wildlife and Rangeland Resources.**

Dr. Robert J. Hudson, Supervisor

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DATE: 21 April 1993

To my wife, Glennys,

for her unwavering support and companionship.

ABSTRACT

North American duck populations are in decline because nesting success rates in the prairie pothole region are below levels required to sustain populations. Predation facilitated by poor nesting cover is a major cause of nest failure. Agricultural activities such as haying and grazing can be destructive to nesting cover, leading to increased predation. This study evaluated the suitability of a commercial deer repellent, derived from whole egg solids, for managing livestock grazing to improve nesting habitat. Three experiments were conducted to measure the responses of vegetation, grazing cattle, waterfowl, and nest predators to applications of Deer-Away Big Game Repellent (BGR). In the first experiment, vegetation growth and grazing by livestock were compared between plots of vegetation treated with BGR and untreated control plots. Vegetation growth was not affected by application of BGR, but cattle grazed treated vegetation less than untreated vegetation. As a result, plant residue accumulation and spring regrowth were greater on BGR treated plots than control plots. In the second experiment, occupation and water consumption by captive ducks were compared between rooms with floor litter either treated or untreated with BGR. Ducks demonstrated no response to the repellent. In the third experiment, predation of artificial nests within plots of vegetation to which BGR was or was not applied were compared. Visits by carnivores to scent stations which were either baited or unbaited with BGR were also compared. Predation of artificial nests was greater within BGR treated plots than control plots, but visits to scent stations did not differ significantly among treatments. BGR apparently attracted predators only when applied to relatively large areas. The cost of using BGR relative to traditional fencing methods varies considerably with the size and shape of the area to be protected. BGR is more cost effective on smaller areas or areas with large perimeter to area ratios. This study demonstrated that repellents are a promising grazing management tool, but indicated several limitations of BGR for managing waterfowl nesting cover.

DISCLAIMER

Mention of trade marks or proprietary products does not constitute a guarantee or warranty of these products by the author or the University of Alberta and does not imply endorsement.

ACKNOWLEDGEMENTS

Numerous individuals contributed to the successful completion of this endeavor I am grateful for the inspiration of Dr. B.A. Young, and my supervisor, Dr. R.J. Hudson. I also wish to thank members of my supervisory committee, Drs. A.W. Bailey, P.H. Crown, M.A. Naeth, and F.E. Robinson for their valuable contributions of timely and sage advice.

The cooperation and logistical support of the Blackfoot Grazing Association; Alberta Department of Recreation and Parks, and the Public Lands and Fish and Wildlife divisions of Alberta Forestry, Lands and Wildlife were appreciated. Also appreciated were the contributions of individuals from these agencies such as Ross Spence, Ed Whitelock, and Chuck Richardson. I thank Dr. John Feddes, Dale Travis, and the Department of Agricultural Engineering, University of Alberta for use of their poultry barn simulation unit, students and staff of the Poultry Unit, University of Alberta Edmonton Research Station for animal care and data collection assistance; and E & P Equipment Rentals of Vegreville, Alberta for exemplary service.

I express appreciation to Dr. A.B. Sargeant, Dr. M.W. Barrett, Dr. D.A. Boag, Dr. J.O. Murie, Ken Lungle, Ernie Ewaschuk and Larry Roy for technical advice and literature contributions. Technical information provided by Jeff Marley of Margo Supplies Ltd. and Ken Williamson of Alberta Agriculture Engineering Branch are also sincerely appreciated. I am deeply grateful to Dr. R.T. Hardin for statistical assistance and to Carol Koch for typing this manuscript.

Gratitude is expressed to the Natural Sciences and Engineering Research Council of Canada for financial contributions. The Recreation, Parks and Wildlife Foundation of Alberta and the Alberta NAWMP Centre (on behalf of the Prairie Habitat Joint Venture) were also generous financial contributors. I thank these agencies and members of their review committees who supported my proposals.

Finally, I extend my heartfelt thanks to family and friends for their encouragement and support.

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INTRODUCTION

1.1 WATERFOWL IN NORTH AMERICA

Waterfowl are an important North American wildlife resource. Their migrations bring brief respites of wilderness experience to urban dwellers and signal the change of seasons in temperate regions. Waterfowl are meaningful to recreationists such as hunters, bird watchers, and photographers, who spend in excess of several billion dollars annually to enjoy these birds (Environment Canada 1986). Interest in waterfowl related activities and industries is growing rapidly and will continue to be important in the future (Environment Canada 1990). Not surprisingly, desire to perpetuate the waterfowl resource is widespread and diverse. Present North American duck populations however, are at historically low levels and continue to decline. This decline is attributed to decline in populations of mallard (*Anas platyrhynchos*), blue winged teal (*A. discors*), and northern pintail (*A. acuta*), which together account for one half of the total breeding duck population in North America (Reynolds 1987).

1.2 CAUSES OF DUCK POPULATION DECLINE

Causes for duck decline range from acid rain (Blancher and McAuley 1987) to selenium, lead, and algal poisoning (Hawkins 1989). However habitat loss to agriculture, urbanization, and industrial development is a major contributor to duck population decline, particularly in the prairie parkland of Canada where half the continental mallard population is produced (Environment Canada 1986, Reynolds 1987, Turner et al. 1987, Nudds and Cole 1991). Losses of original wetlands to filling and drainage range from 40 to more than 90% in many regions of North America (Environment Canada 1986, Turner et al. 1987, Pederson et al. 1989). Despite severe losses, adequate wetlands remain to attract large numbers of breeding ducks but poor nesting success limits population maintenance and growth (Klett et al. 1988). High nesting success depends on sufficient upland nesting habitat (Duebbert and Kantrud 1974) but uplands are even more vulnerable to agricultural disturbances than are wetlands (Greenwood et al. 1987). Productive upland habitat in prairie Canada is restricted to lands marginal for cereal production (Environment Canada 1990). Conversion of these lands to cereal production poses the greatest potential threat to duck production in terms of habitat loss (Greenwood et al. 1987), but existing uses of marginal lands can also have a major influence on nesting success (Duebbert and Kantrud 1974). Agricultural activities on marginal lands include haying and grazing. Heavily grazed wetland margins produce attractive areas for loafing ducks (Sowls 1955, Pederson et al. 1989), but heavy upland grazing is detrimental to nesting cover (Sowls 1955, Duebbert and Kantrud 1974).

Nesting success rates in many areas of the prairie pothole region are well below levels required to sustain present populations (Greenwood et al. 1987, Klett et al. 1988, Environment Canada 1990). The primary cause of nest failure is predation facilitated by poor nesting cover (Greenwood et al. 1987, Hochbaum et al. 1987). Duebbert and Kantrud (1974) stated predation can be managed either by direct predator reduction or by establishment and maintenance of excellent habitat, but preferred the latter practice. Habitat favorable to high nesting success contains tall, dense, concealing cover (Schranck 1972, Livezey 1981). Removal of such cover by mowing or grazing reduces both nest initiation and success (Kirsch 1969, Kirsch et al. 1978).

1.3 HABITAT MANAGEMENT STRATEGIES

Three major strategies are currently employed by conservation agencies in North America to establish and maintain appropriate upland habitat: 1) acquisition of prime habitat areas through purchase or long term lease; 2) paying incentives to landowners to remove land from agricultural production; and 3) encouraging landowners to use alternative land management practices which include specialized haying and grazing systems (Environment Canada 1990). Each of these strategies is important to the establishment of sufficient upland habitat for nesting waterfowl. The third strategy is probably the most attractive to landowners because it allows them to realize the agricultural potential of their land without detriment to wildlife. This strategy also provides the greatest opportunity for innovation in land management practices for both agricultural and wildlife production. Despite potential benefits to landowner and waterfowl, incentives are still required to encourage participation in alternative management practices. The less costly and labor intensive a management alternative is, the more likely it will be adopted by a participating landowner. An ideal management alternative would be one which effectively protected nesting cover; was inexpensive; offered management flexibility; and did not interrupt land use by restricting livestock movement and access to point resources.

1.4 A MANAGEMENT ALTERNATIVE

Management of herbivory by wild ungulates with repellents has been attempted often in agriculture and forestry (Conover 1984, Hyngstrom and Craven 1988, Swihart and Conover 1990). The same approach may be appropriate for protecting nesting cover from livestock grazing, either as an alternative to specialized grazing systems or to enhance their benefits. Of numerous home-made and commercial repellent preparations tested, Deer-Away Big Game Repellent® (BGR) made from putrescent whole egg solids, was one of the most successful in reducing herbivory (Harris et al. 1983, Andelt et al. 1991, 1992, Osko et al. 1993).

1.5 STUDY OBJECTIVE

The objective of this study was to evaluate the suitability of BGR for use in managing waterfowl nesting habitat by testing the responses of vegetation, grazing cattle, ducks, and nest predators to its application. Three experiments were conducted to determine these responses and are described in Chapters 2, 3, and 4. A final evaluation of BGR's suitability for use in habitat management, based on these responses and other criteria, is discussed in the concluding chapter.

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2

RESPONSES OF GRAZING CATTLE AND VEGETATION TO CHEMICAL FENCING WITH DEER-AWAY BIG GAME REPELLENT®

2.1 INTRODUCTION

Taller, concealing vegetative cover generally improves waterfowl nesting success (Livezey 1981, Hines and Mitchell 1983), although extremely dense or tall cover is not preferred by ducks (Sowls 1955). Long (1970) reported several species of ducks preferred moderately dense cover which was 150 to 340 mm tall. Removal of such cover by mowing or grazing reduces both nest initiation and nesting success (Kirsch 1969, Kirsch et al. 1978). Because the presence of cattle is also thought to disturb nesting waterfowl (Kirsch 1969, Barker et al. 1990), exclusion of cattle from lands managed for waterfowl production is often recommended (Kirsch 1969, Livezey 1981).

Specialized grazing systems offer an alternative to total exclusion of cattle from waterfowl habitat without interfering with nesting waterfowl (Mundinger 1976, Barker et al. 1990). Such systems also benefit livestock production by improving forage utilization to increase stocking rates, but involve extra costs in terms of capital expenditures (fencing, water developments) and labor (Sedivec et al. 1990). Landowner participation in cooperative waterfowl habitat management projects might be improved if protection of vegetative cover from grazing was less restrictive of livestock movement and access to point resources such as water. Also, management systems which offer more flexibility than provided by permanent fencing may be more readily adopted. Management of herbivory by wild ungulates with repellents has been attempted often in agriculture and forestry (Conover 1984, Hyngstrom and Craven 1988, Swihart and Conover 1990). The same approach may be appropriate for protecting nesting cover from grazing by livestock, either as an alternative to specialized grazing systems or to enhance their flexibility and effectiveness. Of numerous home-made and commercial preparations tested on several ungulate species, Deer-Away Big Game Repellent® (BGR) (37% putrescent whole egg solids) was one of the most successful in reducing herbivory (Harris et al. 1983, Andelt et al. 1991, 1992, Osko et al. 1993)

This experiment was conducted to evaluate the efficacy of powder and liquid formulations of BGR in reducing grazing intensity by cattle to improve waterfowl nesting habitat. Specific objectives of this experiment were: 1) to determine whether pasture vegetation to which BGR was applied would be grazed less intensively by cattle, thereby increasing nesting cover; 2) to compare the effectiveness of powder and liquid formulations of BGR in deterring grazing by cattle; and 3) to determine whether spatial occupational patterns of cattle were altered by application of BGR to vegetation.

2.2 MATERIALS AND METHODS

2.2.1 Study Area

The study was conducted within the Cooking Lake/Blackfoot Recreation, Wildlife and Grazing Area (Blackfoot Area) in the Beaverhills, 40 km east of Edmonton, Alberta. The Beaverhill Upland is an isolated hill complex developed on hummocky morainal till and is representative of the Low Boreal Mixedwood ecoregion, situated near the northern edge of the Aspen Parkland ecoregion of Alberta (Strong 1992). Soils are predominantly Gray Luvisols. Dominant vegetation is aspen (*Populus tremuloides* Michx.) and balsam (*P. balsamifera* L) poplar, successional to white spruce (*Picea glauca* (Moench) Voss). Black spruce (*P. mariana* (Mill.) BSP.) predominates on imperfectly and poorly drained sites. The varied understory includes reed grasses (*Calamagrostis spp.* Adans.), wildrye (*Elymus spp.* L), pea vine (*Lathyrus spp.* L.), vetch (*Vicia spp.* L), and saskatoon (*Amelanchier alnifolia* Nutt.). Wetlands bordered by mature mixedwood forest support diverse breeding bird communities and are the most productive fur bearer habitats in Alberta (Strong 1992). Proximity to Beaverhills Lake, a major waterfowl staging area, is also relevant to the importance of the Beaverhills as waterfowl habitat.

The study field was a sub-unit of one of seven pastures cleared and reseeded to cultivated forages within the 9712 ha Blackfoot Area. Total area of all improved pastures within the Blackfoot Area was 2850 ha (Alberta Energy and Natural Resources 1983).

Grazing of improved pastures is managed by the Blackfoot Grazing Association on behalf of local farmers and ranchers. The study pasture was 228 ha, 173 ha of which were cleared of woody vegetation in January of 1984. In July of 1986, the pasture was seeded with a mixture of 25% smooth brome (*Bromus inermis* Leyss.), 20% creeping red fescue (*Festuca rubra* L.), 15% orchard grass (*Dactylis glomerata* L.), 15% timothy (*Phleum pratense* L.), 10% alsike clover (*Trifolium hybridum* L.), 10% meadow brome (*Bromus biebersteinii* Roem & Schult.), and 5% meadow foxtail (*Alopecurus pratensis* L.) (C. Richardson, Alberta Forestry, Lands and Wildlife, pers. comm.). The pasture was roughly 2.5 km long by 0.9 km wide, oriented north to south and sloping southward. Topography within the study pasture was hummocky with slopes ranging from 8 to 30%. Slopes within the 8 to 16% range predominated. The pasture contained several large (>5 ha) permanent water bodies as well as numerous small semi-permanent water bodies. Several large (>10 ha) as well as numerous smaller uncleared areas also remained within the pasture.

2.2.2 Experimental Design

Four treatment blocks were located in each of four landscape positions (hilltops, lowlands, north slopes, south slopes) for a total of 16 blocks within the pasture. One of three repellent treatments was randomly assigned to each of three 15 x 20 m plots, separated by a distance of at least 2 m, within each block. Repellent treatments consisted of liquid BGR, powder BGR, and a control (no repellent). The design was a split-plot using landscape positions as main plots and repellent treatments as subplots. Measurement date was included as a sub-subplot for observations recorded on multiple dates. Vegetation species composition was estimated according to Wroe et al. (1988) within 20 x 50 cm quadrats (Daubenmire 1959), placed systematically within treatment plots, to confirm species were similar among repellent treatments. Estimates of ground covered by green vegetation (ground covered by live plant at soil interface), bare soil, and litter were also recorded within the same quadrats.

2.2.3 Treatments

The sequence of procedures during 1991 are summarized in Table 2.1. Repellents were applied to treatment plots on 5 and 6 June 1991 at a rate of 11.8 kg ha^{-1} active ingredient. Powder was applied with a flour sifter while liquid was applied with a backpack sprayer at a volume of 250 L ha^{-1}. BGR was applied again on 16 and 17 June 1991 using the same rates and volumes to ensure applications were fresh prior to the first release of cattle onto the pasture.

Table 2.1. Sequence of procedures during 1991.

Date	Procedure
1, 2, 3 Jun	Canopies measured
5, 6 Jun	BGR applied
16, 17 Jun	BGR applied
18, 19 Jun	Canopies measured
20 Jun	Cattle entered pasture
28 Jun	Cattle left pasture
28, 29, 30 Jun	Canopies measured
12, 13, 14, Jul	Canopies measured
18 Jul	Cattle entered pasture
31 Jul	Cattle left pasture
31 Jul, 1 Aug	Canopies measured
9, 10 Sep	Canopies measured
11 Sep	Cattle entered pasture
3 Oct	Cattle left pasture
11, 12, Oct	Canopies measured

The study pasture was grazed three times over the 1991 season. A herd of cross bred beef cows, calves, and breeding bulls totaling 357 animal units (AU) grazed the pasture for 8 days beginning 20 June 1991. The pasture was grazed by 250 AU for thirteen days beginning 18 July 1991 and 22 days beginning 11 September 1991.

2.2.4 Measurements

The effectiveness of repellents in reducing grazing intensity was determined by comparing canopy measurements of vegetation between repellent and control plots. A non-destructive method for measuring canopies was used, since removal of forage by clipping would remove applied repellents as well. Furthermore, forage removal would negate repeated canopy measurements at the same location over time. Measurements were made by gently resting a 61 x 61 x 2.5 cm sheet of polystyrene foam upon the plant canopy and measuring the height of the sheet above the soil surface (McNaughton 1984). The resting height of the foam board was linearly related to the phytomass beneath it. Relationships of canopy measurements with phytomass are detailed in Appendix A. Measurements were taken at 4 m intervals along three permanent transects within each plot, for a total of 12 measurements per plot.

Canopies were measured on seven occasions from 2 June through 11 October 1991 (Table 2.1). Measurements were recorded prior to initial application of repellents, 14 days after initial repellent application, and before and after each time the pasture was grazed. Counts of fresh cow chips deposited within each plot were also recorded after each grazing period to monitor livestock occupational patterns among repellent treatments and landscape positions (Engle and Schimmel 1984).

Plot canopies were measured again before and after cattle grazed the study pasture for the first time in 1992. Cow chip counts were also recorded for this grazing period. The pasture was grazed by 450 AU for 5 days during this period. Observations in 1992 were recorded to evaluate the consequences of repellent application in one season on canopy measurements and grazing intensity in the next.

2.2.5 Statistical Analysis

Statistical analyses were conducted for canopy measurements, canopy reductions during grazing periods, canopy increases between grazing periods (growth periods) and cow chip counts during grazing periods. Canopy reductions during grazing periods were calculated by subtracting pre-grazing measurements from post-grazing measurements. Canopy increases between grazing periods were calculated by subtracting post-grazing measurements of one period from pre-grazing measurements of the next period. Increases during the period between the first measurement of 1991 (before repellent application) and the second (after repellent application but before grazing) were the difference between the two measurements.

Analysis of variance was performed on 1991 canopy measurements and cow chip counts for both years, using the general linear models procedure of the Statistical Analysis System (SAS 1989). The same procedure was used to perform analysis of covariance on canopy reductions in both years, canopy increases in 1991 (no increases were measured in 1992), and canopy measurements in 1992. Pre-grazing measurements for each grazing period were used as covariates in the analysis of canopy reductions during grazing periods. Post-grazing measurements of a completed grazing period were used as covariates for analysis of canopy increases between that period and the next. Final canopy measurements recorded in 1991 were used as covariates for analysis of the first canopy measurements of 1992. The first canopy measurements of 1992 were used as covariates in the analysis of the second 1992 measurements, and the single grazing period observed in that year.

All data were analyzed as a split-plot using the appropriate split-plot error terms to test main effects and their interactions. Repeated measures analyses were performed on data for which observations were recorded on more than two occasions (Milliken and Johnson 1984). The Greenhouse-Geiser epsilon was used to adjust degrees of freedom. This epsilon is more conservative than the Huynh-Feldt epsilon recommended by SAS (1989).

2.3 RESULTS

2.3.1 Vegetative Composition and Cover

Species composition varied somewhat with landscape position. For example, marsh reed grass (*Calamagrostis canadensis* Michx.) was common on lowland positions but absent elsewhere. Except for a small but statistically significant greater proportion of timothy within plots assigned to liquid BGR, species composition and ground cover among repellent treatments did not differ.

2.3.2 Canopy Measurements

Canopy height differed significantly among repellent treatments and measurement dates. Repellent by date interactions were also significant. Canopy height did not differ among landscape positions in 1991, although landscape by measurement date interactions were significant in that year. In 1992, canopy heights among landscape positions differed, but interactions with measurement dates were not significant.

Canopy height on the first two measurement dates of 1991 did not differ among repellent treatments, but vegetation in powder and liquid BGR treated plots was taller than in control plots on every occasion thereafter in 1991 (Fig. 2.1). Vegetation was also taller in liquid BGR plots than in powder BGR plots on all but one of the remaining occasions in 1991 (Fig. 2.1). Measurements on both liquid and powder BGR plots were taller than control plots for both dates in 1992 (Table 2.2). Vegetation in liquid BGR plots was taller than in powder treated plots on 19 May, but the two did not differ on 28 May 1992.

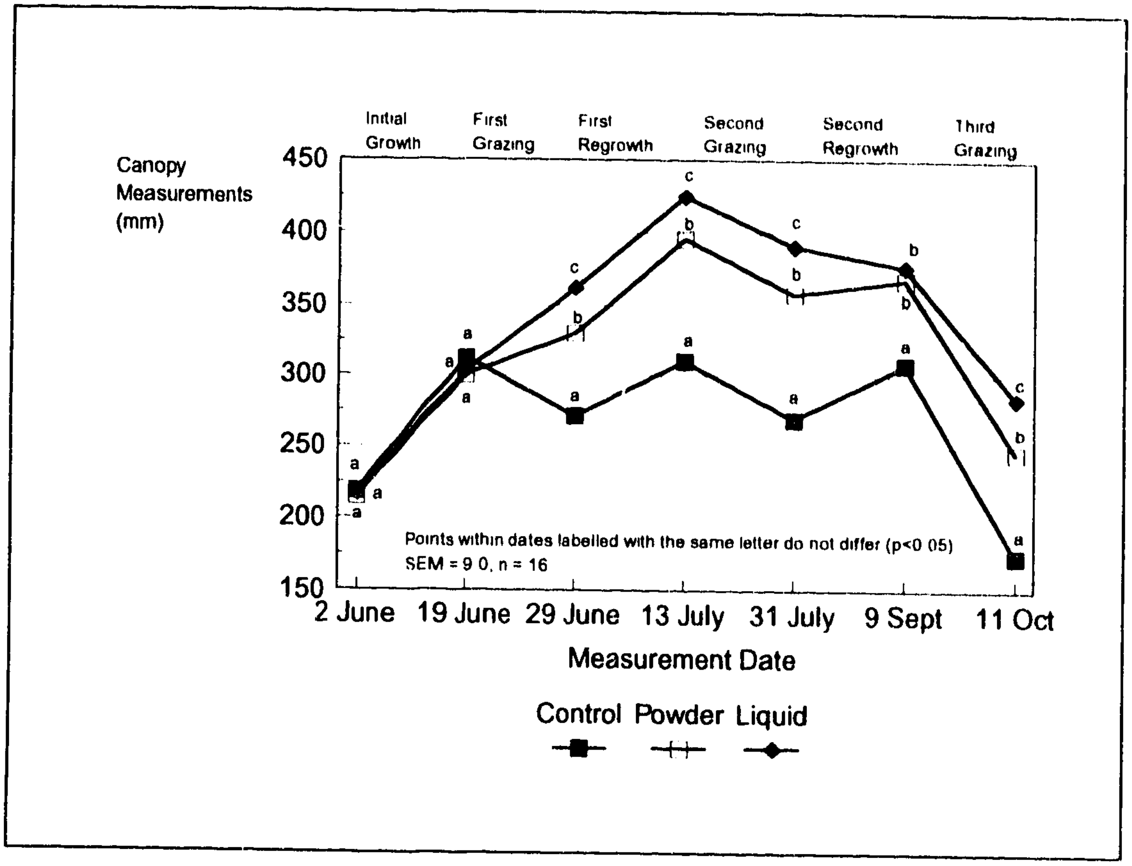

Fig. 2.1. Canopy measurements recorded during 1991 among Big Game Repellent® treatments.

Table 2.2. Canopy measurements recorded before and after initial 1992 spring grazing among Big Game Repellent® treatments.

	Control		Powder		Liquid	
Date	Mean	SEM	Mean	SEM	Mean	SEM
	(mm)					
19 May	138[a]	3.0	164[b]	3.7	173[c]	4.2
28 May	120[a]	3.5	129[b]	3.2	135[b]	3.1

Means within dates followed by the same superscript do not differ ($p<0.05$); n = 16.

Tallest canopies were observed on lowland positions on all but the final measurement date of 1991, when no differences occurred among landscape positions (Table 2.3). Shortest canopies were observed on hilltops and south slopes, which did not differ from each other. North slope canopies did not always differ from the taller lowland, and shorter south slope and hilltop canopies in 1991, but were typically intermediate. Vegetation was tallest on lowland positions (165 mm) again in 1992, while canopies among hilltops (132 mm), south slopes (138 mm) and north slopes (138 mm) did not differ.

Table 2.3. Canopy measurements among landscape positions recorded during 1991.

Date	Hilltops	Lowlands	North Slopes	South Slopes
	(mm)			
2 June (before BGR appl.)	196^{a}	245^{c}	226^{bc}	202^{ab}
19 June (before grazing)	274^{a}	385^{b}	292^{a}	269^{a}
29 June (after grazing)	286^{a}	397^{c}	319^{b}	282^{a}
13 July (before grazing)	248^{a}	462^{c}	374^{b}	323^{a}
31 July (after grazing)	310^{a}	431^{b}	321^{a}	294^{a}
9 Sept. (before grazing)	321^{a}	430^{c}	347^{b}	305^{a}
11 Oct. (after grazing)	220^{a}	245^{a}	246^{a}	228^{a}

Means within dates followed by the same superscript do not differ ($p<0.05$); SEM = 10.4, n = 12.

2.3.3 Grazing

Canopy reductions during grazing periods in 1991 were significantly less on BGR treated plots than on control plots (Table 2.4). Among the two BGR formulations, liquid treatments were more effective deterrents to livestock grazing than powder treatments (Table 2.4). Repellent by grazing period interactions were not significant.

Table 2.4. Changes in canopy height during all three 1991 grazing periods combined among Big Game Repellent® treatments.

Treatment	Mean	SEM
	(mm)	
Control	-102^{a}	8.4
Powder	-35^{b}	6.7
Liquid	-2^{c}	7.4

Means followed by the same superscript do not differ ($p < 0.05$); n = 48.

Interactions of landscape position with grazing period were significant, although the effect of landscape position on canopy reductions was not significant overall. There were no differences in canopy reductions among landscape positions during the final grazing period. During the first two periods, the largest reductions were observed on hilltops and south slopes, followed by north slopes (Table 2.5). Canopies actually grew taller on lowland positions during the first two grazing events. There were no differences in canopy reductions among repellent treatments nor landscape positions for the single grazing period observed in 1992.

Table 2.5. Changes in canopy heights among landscape positions during 1991 grazing periods.

	Hilltops		Lowlands		North Slopes		South Slopes	
Grazing Period	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
	(mm)							
First	-53^{a}	14.1	47^{c}	11.9	-21^{b}	12.8	-56^{a}	14.5
Second	-37^{a}	10.9	75^{b}	18.4	-27^{a}	11.4	-49^{a}	11.2
Third	-116^{a}	11.0	-108^{a}	15.2	-100^{a}	10.8	-113^{a}	12.0

Means within grazing events followed by the same superscript do not differ ($p < 0.05$); n = 12.

2.3.4 Growth

Canopy changes during growth periods did not differ overall among repellent treatments or landscape positions, although both factors had significant interactions with growth period. No differences in canopy growth were detected among repellent treatments during the initial growth period before grazing commenced or between the second and third grazing events. However, canopy height increased much more on BGR treated plots than on control plots between the first and second grazing periods (Table 2.6). Canopy growth was greatest within control plots during the initial period prior to grazing, while increases between grazing events were less than half of the initial increase. On the other hand, canopy increases were largest within BGR plots between the first and second grazing events, followed by the initial period before grazing, and finally between the second and third grazing events (Table 2.6).

Table 2.6. Changes in canopy height before initial grazing and between grazing periods (growth) in 1991 among Big Game Repellent® treatments.

	Control		Powder		Liquid	
Growth Period	Mean	SEM	Mean	SEM	Mean	SEM
	(mm)					
Initial	65[a]	7.5	55[a]	7.6	57[a]	7.6
Between grazing 1 and 2	30[a]	5.9	86[b]	6.2	89[b]	7.3
Between grazing 2 and 3	32[a]	5.8	34[a]	7.1	23[a]	8.6

Means within growth periods followed by the same superscript do not differ ($p<0.05$); n = 16.

Among landscape positions, the largest increases in canopy measurements during growth periods were generally observed on lowlands while the smallest increases were observed on south slopes (Table 2.7). Increases on north slopes and hilltops were intermediate between the two extremes but did not always differ from them significantly.

Table 2.7. Changes in canopy heights before initial grazing and between grazing periods (growth) among landscape positions in 1991.

	Hilltops		Lowlands		North Slopes		South Slopes	
Growth Period	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
	(mm)							
Initial	41[a]	9.2	122[b]	7.3	40[a]	7.9	33[a]	8.9
Between grazing 1 and 2	68[b]	6.6	105[c]	9.4	65[b]	6.8	37[a]	6.6
Between grazing 2 and 3	18[a]	6.7	51[b]	11.2	40[b]	7.0	11[a]	6.6

Means within growth periods followed by the same superscript do not differ ($p < 0.05$); n = 12.

2.3.5 Cow Chip Counts

Cow chip counts recorded in 1991 did not differ among repellent treatments but did differ among landscape positions and grazing events. Landscape by grazing event interactions were also significant. Cow chip counts were highest on hilltops during two of the three grazing events and highest on hilltops overall (Table 2.8). Counts were highest in lowlands during the first grazing event, but generally did not differ among the three landscape positions other than hilltops during the 1991 season. Cow chip counts generally increased with time spent in the pasture during each grazing event. There were no differences in cow chip counts during 1992.

Table 2.8. Cow chip counts among landscape positions during 1991 grazing periods.

Grazing Event	Hilltops	Lowlands	North Slopes	South Slopes
	cow chips			
First	7[ab]	11[b]	5[ab]	3[a]
Second	12[b]	4[a]	7[ab]	4[a]
Third	31[b]	9[a]	11[a]	11[a]

Means within grazing events followed by the same superscript do not differ ($p < 0.05$); SEM = 2.34, n = 12.

2.4 DISCUSSION

2.4.1 Grazing Among Repellent Treatments

Application of BGR had little effect on vegetation growth. However, BGR apparently influenced grazing intensity because BGR treated vegetation was taller than untreated vegetation from the time grazing commenced. Furthermore, vastly larger reductions in canopies occurred on control plots than on BGR treated plots during grazing, particularly compared to liquid treatments. It is doubtful that the small difference in proportion of timothy among treatments would result in such large differences in canopy reductions during grazing.

Although BGR protected vegetation from grazing, it is not likely that BGR remained actively repellent for the entire 18 or more weeks of the season. Oita et al. (1977) and BGR manufacturers suggested the product should actively repel ruminants for about 8 weeks. Grazing preferences of cattle were probably influenced by the presence of BGR during the first grazing period, causing cattle to avoid BGR treated plots. Cattle were observed to enter plots treated with BGR, sniff or sample the vegetation, then proceed 10 to 15 m beyond the plots before commencing grazing. Relatively untouched, vegetation within BGR treated plots was allowed to mature compared to forage maintained in a vegetative state by grazing within control plots. Patterns established during the initial grazing period were likely perpetuated during subsequent periods by this difference in phenological state of vegetation between BGR and control plots. This was demonstrated by the interactions between canopy measurements and dates. Canopies on control plots were reduced during the first grazing period, indicative of biomass reduction by grazing cattle. Meanwhile, canopies on BGR treated plots increased during the same period, suggesting biomass accumulation despite the presence of grazers. By the time plot canopies were measured prior to the next grazing period, virtually all of the vegetation within BGR treated plots had flowered. BGR apparently no longer repelled cattle from grazing during subsequent events because canopies were reduced regardless of treatment.

However, reductions on BGR treated plots during the final grazing period were due as much or more to trampling of senescent material as to grazing. In fact, vegetation within liquid BGR treated plots was senescing by the end of July and had begun to lodge.

2.4.2 Vegetative Response

Because cattle consumed less forage from BGR treated plots, more photosynthetic tissue remained intact on vegetation within these plots over the course of the growing season. Enough stubble remained on BGR plots after the first grazing period to provide sufficient photosynthetic activity to meet total respiratory requirements (maintenance and growth) of vegetation within these plots, allowing plants to continue biomass accumulation (Davies 1988). Conversely, vegetation within more severely defoliated control plots may not have retained enough photosynthetic tissue to adequately meet respiratory needs. Therefore, the use of available carbon resources may have been required to initiate regrowth of new photosynthetic material (Davies 1988).

Vegetation protected from grazing by application of BGR would have had a distinct competitive advantage over unprotected vegetation. Protected vegetation would have produced and accumulated more photosynthate while expending less energy on regrowth than unprotected vegetation. BGR treated vegetation would therefore have been better prepared for winter survival and spring regrowth (Walton 1983). Spring regrowth on BGR treated plots in 1992 was much more vigorous than growth on adjacent control plots, as indicated by 1992 canopy measurements.

2.4.3 Grazing Among Landscape Positions

BGR was equally effective among landscape positions as there were no interactions of repellent with landscape position. Differences in canopy measurements, canopy reductions during grazing, and growth among landscape positions probably related to differences in growing conditions and forage species (Holechek et al. 1989). For example, soil moisture was probably more available in lowland positions than on hilltops and south slopes. Similarly, soils were likely cooler on north slopes and lowlands than in the other positions. These conditions may have produced greater vegetative growth on lowlands and north slopes later in the season relative to hilltops and south slopes. Smaller reductions of canopy measurements on lowlands probably related most to species composition. Marsh reed grass, which is relatively unpalatable (Looman 1983), was a substantial component of lowland vegetation but did not exist in other positions. In addition, meadow foxtail was also more dominant on lowlands than other positions. Meadow foxtail is palatable but also matures early (Alberta Agriculture 1988), which may have reduced its palatability in relation to plants in other landscape positions.

2.4.4 Benefits to Waterfowl

The ability of BGR to protect vegetation from grazing and allow it to grow relatively uninterrupted early in the season is particularly beneficial to waterfowl, since adequate cover during peak nesting activity will improve nesting success (Livezey 1981). Although the forage height measuring technique used by Long (1970) and the canopy measurement technique used here are not directly comparable, it would appear that vegetation on control plots remained near the minimum of the range reported by Long (1970) for optimal nesting cover. On the other hand, vegetation on BGR plots was maintained near the maximum of this range until fall. Application of BGR may also benefit waterfowl nesting in the second season after application since residue accumulation over the previous season improves nesting conditions (Kirsch 1969, Hines and Mitchell 1983, Barker et al. 1990). Furthermore, even though BGR provided no protection from grazing without reapplication the second year, improved spring growth on areas initially treated with BGR would provide better cover than new growth on untreated areas. Application of BGR may also benefit wild ungulate species. Since repellency of BGR is not permanent, forage residue accumulated over the growing season on strategically located protected areas would provide a palatable winter food reserve.

Using cow chip counts as an indicator of areas occupied by cattle, cattle apparently spent more time on hilltops in this experiment than on any of the other three landscape positions observed. Cattle seemed to prefer hilltops for loafing, which explains the high cow chip count on these positions. Despite reducing grazing where it was applied, BGR did not prevent cattle from occupying treated areas. Although disturbance of nesting ducks by the presence of grazing cattle has been implied in literature, the subject has not been studied extensively. Further investigation is required to determine the relationships between cattle presence and nest initiation and success in areas with adequate nesting cover.

2.4.5 Conclusion

Vegetation to which BGR was applied was grazed less intensively by cattle than similar untreated vegetation. As a result, vegetative cover for potential waterfowl nesting was increased where BGR was applied. The liquid formulation of BGR was more effective than powder in reducing grazing in this experiment. Although BGR reduced grazing where it was applied, it did not prevent cattle from occupying treated areas.

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3

RESPONSE OF CAPTIVE DUCKS TO DEER-AWAY BIG GAME REPELLENT®

3.1 INTRODUCTION

Deer-Away Big Game Repellent® (BGR) reduces herbivory by deer and cattle (Harris et al. 1983, Andelt et al. 1991, 1992, Osko et al. 1993). BGR could potentially improve management of cattle grazing to protect nesting cover for waterfowl production when used in conjunction with, or as an alternative to specialized grazing systems. Oita et al. (1977) suggested odorous oxidation products of BGR's active ingredient (egg solids) repelled ungulates, but it is unknown whether waterfowl would also be repelled. This experiment evaluated behavioral responses of captive ducks to BGR to determine whether its application to vegetation might influence nesting behavior of waterfowl. Captive ducks were offered a choice of environments in which BGR was either present or absent, and water consumption and time spent within these environments were compared.

3.2 MATERIALS AND METHODS

3.2.1 Ducks

Rearing and testing facilities were located at the Poultry Unit of the University of Alberta Edmonton Research Station. The protocol for this experiment was approved by the University of Alberta Animal Policy and Welfare Committee. Thirty birds of mixed sex of the Dark Rouen breed of *Anas platyrhynchos* were acquired commercially as day-old ducklings. Ducklings were reared six per cage within Petersime™ battery cages for 21 days. Ducklings were then transferred, three per cage, to 76 x 76 x 46 cm chicken grower cages, where they were reared for the following 31 days. At this time, colored hog ear tags were affixed to the right wing of each bird for later identification. Mates from each grower cage were affixed with the same color tag. After tagging, ducks were transferred to a 3.4 x 4 m pen, where all 30 birds were housed as one group. Ducks remained in this pen for the duration of the study when not directly involved in behavior testing. The photoperiod was 24 hours of light (24 h L: 0 h D) during rearing in cages and the large pen. Behavior observations began when ducks were 66 days old. Ducks were fed a 21%

protein duck and goose starter ration for the first three weeks, and a 16% protein grower ration thereafter. Feed and water were available ad libitum.

3.2.2 Testing Pens

Two testing pens were constructed by modifying four existing ventilated chambers previously used to study environmental effects on poultry growth and health. The chambers were constructed within a barn, with two located along the east and two located along the west walls of the barn. Chambers measured 3.4 x 4 m with a 2.4 m ceiling. Adjacent pairs were separated by a common wall, while opposite chambers were separated by a 3.6 m corridor along the center of the barn. One meter wide corridors were constructed across this central space to connect opposite chambers. Openings for duck access to chambers were produced by cutting the bottom 0.6 m away from 0.8 m wide human-entry doors to the chambers. This arrangement produced one north and one south pen, each containing three compartments: east chamber, west chamber, and central corridor. Each pen was a mirror image of the other (Fig. 3.1).

Negative pressure was maintained within chambers to prevent odors from escaping into central corridors or other chambers. Each chamber was equipped with a variable speed exhaust fan which was adjusted to the minimum speed that produced negative pressure within the chamber. Relative pressure at chamber/corridor interfaces was determined by dropping a feather from the corridor side of chamber doorways directly above the openings cut into them, and observing whether the feather was drawn into the chamber. Each chamber was equipped with a single automatic bell-type poultry drinker and single hanging-pail self-feeder which provided ad libitum feed and water. Lighting within chambers was pre-set to turn off at the same time each night for nine hours (15 h L: 9 h D).

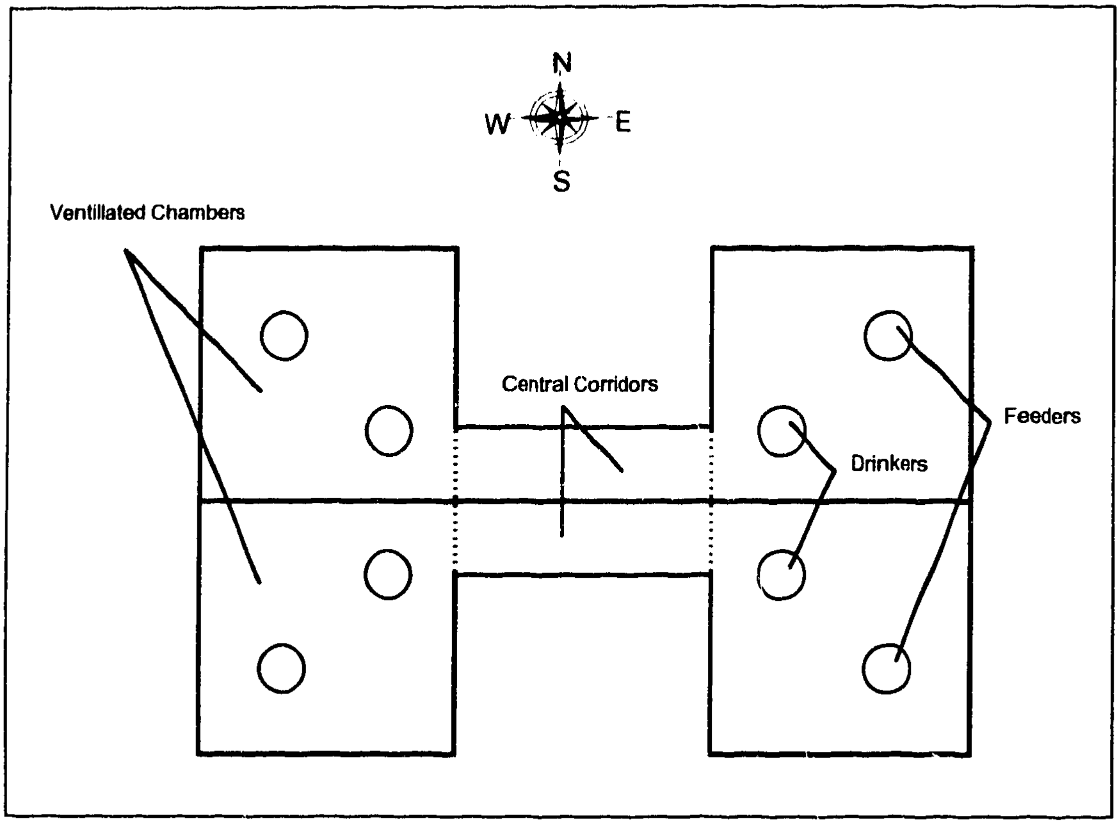

Fig 3.1. Behavior testing pens, each containing two ventilated chambers connected by a central corridor.

3.2.3 Treatments

Ducks were exposed to two pen treatments in which BGR was applied to floor litter (straw) in one or another of the ventilated chambers within a pen. In the first treatment, BGR was applied to the east chamber in the south pen, and to the west chamber in the north pen. Applications were then reversed for the second treatment. BGR solutions were prepared according to label directions and applied at a volume of 50 ml m^{-2} using a one liter capacity, hand held pressurized sprayer. The resulting application rate was 2.36 mg m^{-2} active ingredient. Floors and the bottom 0.5 m of all walls within chambers were covered with polyethylene film prior to spreading litter on chamber floors and spraying with BGR, to prevent contamination of chambers with the repellent. Fresh litter and polyethylene film were used for each treatment.

Each treatment lasted five days. Two groups of ducks consisting of three cage mates each, were captured from the large pen and placed into the testing pens (one group per pen). All three ducks were released at once from the middle of the central corridor connecting opposite chambers. Duck groups remained in testing pens for approximately 24 hours, at which time they were replaced with another group of three cage mates. This process continued daily until all thirty ducks (10 groups) had been exposed to a treatment. Patent documentation (Oita et al. 1977) and label information indicated BGR should remain effective for four to eight weeks. Therefore, the repellent was only applied on the first day of each treatment.

An adaptation period was provided for ducks to become familiar with testing pens prior to exposing duck groups to BGR treatments. Duck groups were released into pens and replaced every 24 hours as described for repellent treatments, but no BGR was applied to chambers during the adaptation period. Allocation of duck groups to pens and the sequence of daily group replacement were randomly assigned during the adjustment period. These allocations were repeated for treatments.

3.2.4 Measurements

A video camera equipped with a 4.5 mm focal length lens was attached to the ceiling above the central corridors connecting chambers. The camera provided a complete view of each corridor and about 20 cm into each chamber. Video recordings during treatments enabled determination of time spent within the compartments of each pen. Behavioral observations of ducks within corridors and at corridor/chamber interfaces were also possible. Elapsed time was entered directly onto video tape by the recorder. Total time spent by ducks within pen compartments was determined by observing duck group movement among compartments and recording time elapsed between entering and exiting each compartment. Times for each compartment were totaled for every duck group-day. Observations were terminated after 22 hours each day to compensate for daily variations in time required to replace ducks, fill feeders, and maintain equipment. Lighting remained on constantly above the corridors to supply light for the camera.

Water consumption was recorded electronically by load cells connected to four (one per chamber) 100 liter barrels, which supplied water to the drinkers. Millivolt signals from load cells were received by a data recorder which converted the signal to volts for display and recording onto magnetic disk. Load cells were calibrated for conversion from volts to kilograms. Water consumption within chambers by ducks was determined from barrel weight loss during the same 22 hour periods observed on video.

3.2.5 Statistical Analysis

The experimental design was a split plot where testing pens were the main plot, BGR treatments were subplots, and pen compartments were sub-subplots. The appropriate split plot error terms were used to test all effects and interactions. Analyses of variance were conducted using the general linear models procedure of the Statistical Analysis System (SAS 1989). Total time spent by duck groups within pens for each treatment was fixed (i.e. total time = 1320 minutes). Therefore, meaningful comparisons could not be made among main effects for video observations because their sums of squares were always zero. The treatment by pen compartment interaction was used to detect significant changes in duck occupation of compartments in response to BGR applications. Water consumption was not fixed, therefore meaningful comparisons were possible among main effects.

3.3 RESULTS

No significant differences were detected in time spent within pen compartments, although there was a relatively large increase in time spent within corridors when BGR was applied to west chambers (Table 3.1). Variability among duck groups was high, as shown by the interaction of pen compartments with duck groups within pens (Fig. 3.2).

Table 3.1. Comparison of time spent by ducks within pen compartments in response to application of Big Game Repellent® within east or west chambers.

Pen Compartment	BGR in East Chamber	BGR in West Chamber
	Treatment	
	------------------------ (minutes) ------------------------	
Central Corridor	494	636
East Chamber	464	411
West Chamber	362	273

Means within pen compartments did not differ between treatments ($P > 0.05$); SEM = 215, n = 10.

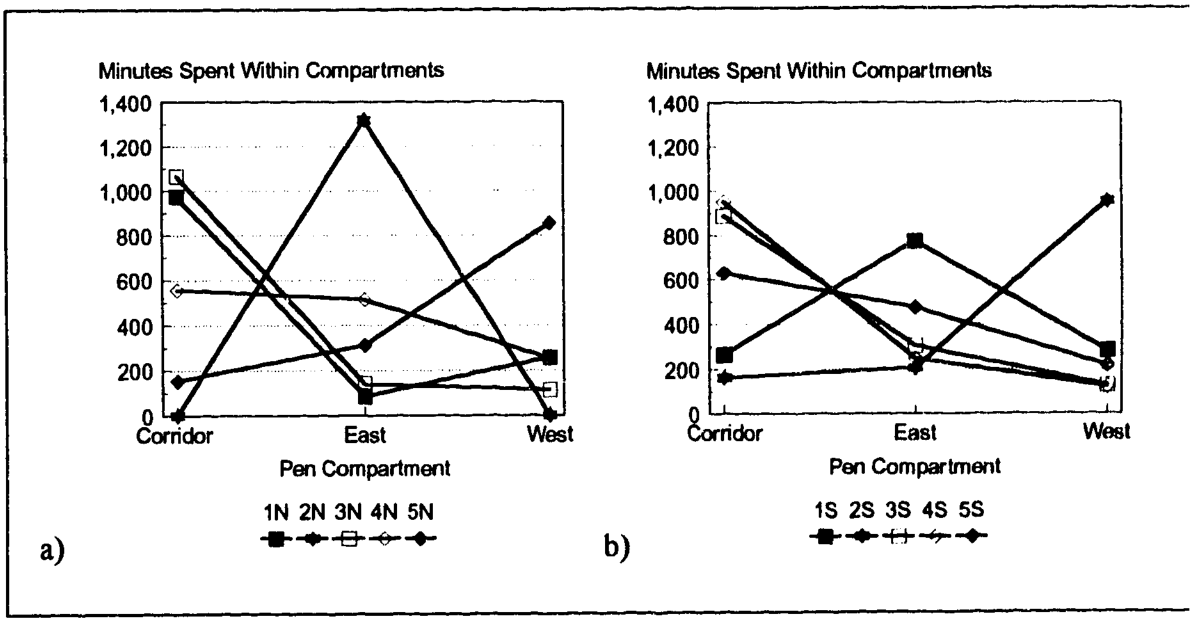

Fig. 3.2. Interaction of pen compartments with duck groups within a) north pen; and b) south pen.

The cause of this variability is uncertain, but it may have been reduced by using a more extensive adaptation period or longer observation periods. Even if the observed changes in compartment occupation had been significant, it is doubtful that they represented a response to BGR. Time spent within west chambers did decrease when BGR applications were switched to west from east chambers. However, time spent within east chambers also decreased during the same treatment. Time spent in both chambers appeared to be traded for time spent within corridors when BGR was applied to west chambers.

Failure of the data logger to record signals during two days of the first treatment made comparisons of water consumption possible among only six duck groups rather than ten. No significant differences were observed among main effects or interactions in water consumption within chambers. Neither were there any meaningful trends.

3.4 DISCUSSION AND CONCLUSION

Absence of a response to BGR by ducks in this study may have been due simply to lack of olfactory discrimination, according to the theory that all bird species are anosmic (Soudek 1927, Walter 1943, cited in Portmann 1961). However, anatomical evidence indicates olfactory structures of avian brains are well developed, highly differentiated, and therefore biologically functional (Portmann 1961, Pearson 1972, Ebinger et al. 1992). Among bird orders, olfactory development in anseriform birds is intermediate. The ratio of diameter of olfactory bulbs to diameter of the entire hemisphere of avian brains ranges from 5 to 30% (Pearson 1972). This ratio is 19% in *Anas platyrhynchos* (Pearson 1972).

In addition to morphological information, behavioral evidence exists for functional olfaction in numerous orders of birds. Odor discrimination has been reported among passerine bird species (Clark and Mason 1987, 1989, Clark and Smeraski 1990), for which the bulb to hemisphere ratio is about 9%. Olfaction apparently plays a significant role in homing behavior of pigeons *(Columba livia)* (Benvenuti and Brown 1989, Wallraff et al.

1989, Ioale and Nozzolini 1990, Schlund 1992), which also have a smaller bulb to hemisphere ratio than ducks. Healy and Guilford (1990) proposed enlarged olfactory bulbs were an evolutionary adaptation in nocturnal and crepuscular birds to compensate for reduced vision under low-light conditions. Jones (1975), Jones and Faure (1982), and Jones and Gentle (1984) presented evidence that domestic chicks *(Gallus domesticus)* recognize odors and that their behavior was modified by olfactory stimuli. Finally, Wurdinger (1979) reported that olfaction influenced the feeding behavior of geese (*Anser spp.)*.

Evidence is lacking in the current literature which links odor discrimination with nesting or breeding behavior in anseriform birds, although such links may occur in other orders (Clark and Smeraski 1990). Whether or not olfaction plays a role in nesting behavior of waterfowl, olfactory anatomy and function are well developed in these birds. It cannot be stated conclusively that application of BGR to nesting cover will not influence nesting behavior because the role of olfaction (if any) in nesting behavior is unknown. However, captive ducks did not respond to the presence of BGR during non-nesting activities in this study. If olfaction does not play a role in nest-site selection, application of BGR to nesting cover probably will not influence nesting behavior.

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4

RESPONSES OF NEST PREDATORS TO DEER-AWAY BIG GAME REPELLENT®

4.1 INTRODUCTION

Deer-Away Big Game Repellent® (BGR) reduces herbivory by deer and cattle (Harris et al. 1983, Andelt et al. 1991, 1992, Osko et al. 1993). BGR could potentially improve management of cattle grazing to protect nesting cover for waterfowl production, when used in conjunction with or as an alternative to specialized grazing systems.

BGR contains egg solids as well as aliphatic aldehydes and their precursors (Oh and Oita 1976, Oita et al. 1977a, 1977b). The product also has a slight fermented egg odor (BGR Technical Report, IntAgra Inc.). Fermented egg and aldehydic compounds attract several predator species (Bullard et al. 1978, Turkowski et al. 1983) and egg solids alone are probably attractive to nest predators. Increased predation because of attraction of predators to BGR application areas n[illegible] preclude its usefulness in managing grazing to protect nesting cover. This study was und[illegible]ken to determine whether nest predators were attracted to areas to which BGR [illegible]ied and to identify species attracted by the repellent.

4.2 MATERIALS AND METHODS

4.2.1 Study Area

The study was conducted within the Cooking Lake/Blackfoot Recreation, Wildlife and Grazing Area (Blackfoot Area) in the Beaverhills, 40 km east of Edmonton, Alberta. The Beaverhill Upland is an isolated hill complex developed on hummocky morainal till and is representative of the Low Boreal Mixedwood ecoregion situated near the northern edge of the Aspen Parkland ecoregion of Alberta (Strong 1992). Soils are predominantly Gray Luvisols. Dominant vegetation is aspen (*Populus tremuloides* Michx.) and balsam (*P. balsamifera* L) poplar, successional to white spruce (*Picea glauca* (Moench) Voss). Black spruce (*P. mariana* (Mill.) BSP.) predominates on imperfectly and poorly drained sites. The varied understory includes reed grasses (*Calamagrostis spp.* Adans.), wildrye

(*Elymus spp.* L), pea vine (*Lathyrus spp.* L.), vetch (*Vicia spp.* L), and saskatoon (*Amelanchier alnifolia* Nutt.). Wetlands bordered by mature mixedwood forest support diverse breeding bird communities and are the most productive fur bearer habitats in Alberta (Strong 1992). Proximity to Beaverhills Lake, a major waterfowl staging area, is also relevant to the importance of the Beaverhills as waterfowl habitat.

The study pasture was a sub-unit of one of seven pastures cleared and reseeded to cultivated forages within the 9712 ha Blackfoot Area. Total area of all improved pastures within the Blackfoot Area was 2850 ha (Alberta Energy and Natural Resources 1983). Grazing of improved pastures is managed by the Blackfoot Grazing Association on behalf of local area farmers and ranchers. The study pasture was 228 ha, 173 ha of which were cleared of woody vegetation in January of 1984. In July of 1986, the pasture was seeded with a mixture of 25% smooth brome (*Bromus inermis* Leyss.), 20% creeping red fescue (*Festuca rubra* L.), 15% orchard grass (*Dactylis glomerata* L.), 15% timothy (*Phleum pratense* L.), 10% alsike clover (*Trifolium hybridum* L.), 10% meadow brome (*Bromus biebersteinii* Roem & Schult.), and 5% meadow foxtail (*Alopecurus pratensis* L.) (C. Richardson, Alberta Forestry, Lands and Wildlife, pers. comm.). The pasture was roughly 2.5 km long by 0.9 km wide, oriented north to south and sloping southward. Topography within the study pasture was hummocky with slopes ranging from 8 to 30%. Slopes within the 8 to 16% range predominated. The pasture contained several large (>5 ha) permanent water bodies as well as numerous small semi-permanent water bodies. Several large (>10 ha) as well as numerous smaller uncleared areas also remained within the pasture.

4.2.2 Predator Species

Sargeant et al. (1992) listed the following species as significant predators of duck nests within the prairie pothole region, the northern limits of which include the study area: coyote (*Canis latrans*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk

(*Mephitis mephitis*), badger (*Taxidea taxus*), mink (*Mustela vison*), weasels (*M. erminea* and *M. frenata*), Franklin's ground squirrel (*Spermophilus franklinii*), black-billed magpie (*Pica pica*), American crow (*Corvus brachyrhynchos*), ring-billed gull (*Larus delawarensis*) and California gull (*L. californicus*). No census of mammalian nest predators has been undertaken within the Blackfoot Area. However, all of the listed mammals except raccoon and Franklin's ground squirrel have been observed there (J. Gray, local trapper, pers. comm.). All of the bird species listed occur within the Blackfoot Area (Blackfoot Area Bird Checklist, Alberta Recreation and Parks). Coyotes were frequently observed within the study pasture, as were black-billed magpies and American crows (pers. obs.).

4.2.3 Simulated Nest Predation

The simulated nest predation study was part of an experiment on the effectiveness of two formulations of BGR in reducing grazing by cattle (Osko 1993). Four treatment blocks were located in each of four landscape positions (hilltops, lowlands, north slopes, south slopes), totaling 16 blocks within the study pasture. One of three repellent treatments was randomly assigned to each of three 15 x 20 m plots, separated by at least 2 m, within each block. Repellent treatments were liquid BGR, powder BGR, and a control (no repellent). The experiment was a split plot design with landscape positions as main plots and repellent treatments as subplots.

Repellents were applied to treatment plots on 5 and 6 June 1991 at a rate of 11.8 kg ha^{-1} active ingredient. Powder BGR was applied with a flour sifter, whereas the liquid was applied with a backpack sprayer at a volume of 250 L ha^{-1}. BGR was reapplied on 16 and 17 June to ensure fresh treatments were applied prior to release of cattle onto pasture on 20 June. Measurements of vegetation canopies were recorded before initial application of BGR and again prior to release of cattle onto the pasture. Differences in these measurements were compared to detect differential plant growth among repellent treatments. Canopy measurements were also used as an indication of relative height and density of nesting cover among landscape positions. Canopy measurements were made by gently resting a 61 x 61 x 2.5 cm sheet of polystyrene foam upon the plant canopy and measuring the height of the sheet above the soil surface (McNaughton 1984). Measurements were taken at 4 m intervals along three longitudinal transects, spaced equally across each plot, for a total of 12 measurements per plot.

Ten simulated duck nests were placed systematically at 4 and 5 m intervals along the 3 transects within each plot. A nest bowl was scraped from the ground litter, into which 3 white chicken eggs were placed. The eggs were then concealed with available vegetation to give as authentic an appearance as possible. Nests were placed on 9, 10, and 11 June and inspected for predation on 18, 19 and 20 June. Any nests with one or more eggs eaten or missing were recorded as predated. A list of potential predators was developed from predator species within the Blackfoot Area by comparing evidence at nests against key depredation characteristics for each species, as outlined by Alan B. Sargeant of the Northern Prairie Wildlife Research Center in North Dakota (pers. comm.).

Statistical analyses were conducted for canopy measurements and nest predation. Analyses of variance were performed using the general linear models procedure of the Statistical Analysis System (SAS 1989). Measurement date was added to the canopy measurement model as a sub-subplot. The appropriate split plot error terms were used to test main effects and their interactions.

4.2.4 Scent Stations

A standard scent station technique (Linhart and Knowlton 1975, Linhart et al. 1977, Roughton and Bowden 1979, Turkowski et al. 1979, 1983) was modified to further evaluate the attraction of predators to BGR and to collect physical evidence with which to identify attracted predators. Twenty-two circular plots of cleared ground were distributed evenly over the study field in June of 1992. Plots, or stations, were separated by at least 300 m and were situated at local topographical lows to reduce potential influence of station odors on each other. Masonry sand was raked evenly over each station to a depth of 4 cm and brushed smooth. Ten centimeter long wicks were supported 4 cm above the sand surface over the center of each station by nailing them to the top of dowels driven into the soil. Half of the wicks were impregnated with BGR solution and allocated randomly to 11 of the 22 stations. Wicks were impregnated by soaking for 2 minutes in a BGR solution prepared according to label directions, followed by drying in air for 12 hours. Impregnated and non-impregnated wicks were handled separately, using separate containers and rubber gloves for each. Non-impregnated wicks were installed first, followed by installation of impregnated wicks.

Wicks were installed on 11 June 1992 and inspected between 1500 and 1700 h daily, for 5 days beginning 12 June. Tracks left in the sand by visiting mammals were identified, recorded and brushed out to leave a smooth surface for detecting subsequent visits. A visit by a species was defined as one or more tracks of that species within a scent station during a given exposure-day (Roughton and Bowden 1979). Evidence of behavioral responses such as urination, defecation, digging, or pulling out wicks (Linhart et al. 1977, Turkowski et al. 1979, 1983) were also recorded.

Frequency of visits by carnivores to scent stations during the 55 exposure-days for each treatment were compared. Significant differences in visit frequencies were determined by chi-square using a statistic derived from a 2 x 2 contingency table with one degree of freedom (Steel and Torrie 1980).

4.3 RESULTS

4.3.1 Simulated Nest Predation

Canopy heights among repellent treatments did not differ on either measurement occasion. Vegetation growth between measurements also did not differ among repellent treatments. Significant differences were detected in canopy measurements among landscape positions, however (Table 4.1). Canopies were tallest in lowlands, followed by north slopes, hilltops, and south slopes. Growth was also greatest in lowlands, but did not differ among other landscape positions.

Table 4.1. Canopy measurements representing nesting cover among landscape positions.

	Landscape Position			
Date	Hilltops	Lowlands	North Slopes	South Slopes
	(mm)			
2 June	196^{a}	245^{c}	226^{bc}	202^{ab}
19 June	274^{ab}	385^{c}	292^{b}	269^{a}
Interperiod Growth	78^{a}	140^{b}	66^{a}	67^{a}

Means within rows followed by the same superscript do not differ ($P<0.05$). SEM = 22.8, n = 12 and SEM = 9.5, n = 12; for measurement dates and interperiod growth, respectively.

Although nesting cover did not differ among repellent treatments, nest predation did. Fewer nests were predated within untreated control plots than either of the repellent treated plots (Table 4.2). Differences among landscape positions were not significant, although they were larger than differences among repellent treatments (Table 4.2). Predation was generally greatest where vegetation was most sparse, but predation among blocks within landscape positions was highly variable.

Table 4.2. Predation of simulated nests among Big Game Repellent® treatments and landscape positions.

	Number of Nests Predated out of 10 Possible	
Treatment	Control	6.4[a]
(SEM = 0.42, n = 16)	Powder	7.8[b]
	Liquid	7.8[b]
Landscape Position	Hilltop	9.1[a]
(SEM = 1.5, n = 12)	Lowland	4.2[a]
	North Slope	8.4[a]
	South Slope	7.8[a]

Means within treatment or landscape position followed by the same superscript do not differ ($P > 0.05$).

It was not possible to identify predators of specific nests with complete certainty because nests were not examined daily. Identification of original nest predators would have been precluded by evidence left by subsequent predators to nests visited by more than one species. It was possible to eliminate a number of potential predators to determine which predators were active within the study field, however. Red fox was eliminated as an active nest predator within the study field because red fox abundance varies inversely with coyote abundance (Johnson et al. 1989, Sargeant et al. 1987, 1992) and because no evidence characteristic of red fox predation was observed. Mink was eliminated because mink do not travel extensively in uplands, where all of the nest sites were located. Gulls were also eliminated because vulnerability of nests to predation by gulls is low to zero in upland habitats. Finally, badger was eliminated because no evidence indicative of badger depredation was detected. Remaining potential predators of nests within the study field included coyote, weasels, striped skunk, black-billed magpie, and American crows. Evidence implicating all of these species was found among the simulated nests. Nests on exposed hilltop positions appeared to be predated predominantly by the avian species.

Nests in denser cover, especially on lowlands and north slopes, appeared to be predated mostly by striped skunk and weasels.

4.3.2 Scent Stations

Five carnivore visits were made to BGR treated stations compared to one carnivore visit made to untreated stations during the 110 exposure days (55 per treatment). All visits were made by coyote. The resultant chi-square ($\chi^2 = 2.82$, d.f. = 1) was not significant at $P<0.05$, but was significant at $P<0.10$. Behavioral responses were limited to a single exposure which occurred at a BGR baited station. Responses included urination and digging.

4.4 DISCUSSION AND CONCLUSION

Nest predators were attracted to BGR, but it was apparently attractive only when applied to relatively large areas. When applied to plots of vegetation, BGR provided an olfactory stimulus which guided predators to application areas. This was demonstrated within one treatment block where a conspicuous nest within the control plot was left intact, while better concealed nests within nearby repellent plots were predated. Olfactory cues, probably used by nocturnal animals, were more important in predation of nests in this location than were visual cues. The influence of BGR applied to nesting cover would be restricted to predation by mammals. BGR would have little effect on predation by avian species because these predators locate nests primarily by sight (Sugden 1987, Alan B. Sargeant pers. comm.).

The variability observed in predation among landscape positions was probably caused by density dependent predation. There was a high probability of discovering all nests within a block once the first nest was discovered because nest densities within blocks were extremely high (Sugden and Beyersbergen 1986). Despite the likelihood of density dependent predation, nests within BGR treated plots were located by predators more frequently than within control plots. How application of BGR to nesting cover would influence predation of natural nests is uncertain. In practical use, BGR application areas might encompass several hectares and natural nest densities would be very much lower. Mammalian predators may become confused by the lack of a point source for odors within a very large odor field. Therefore nest searching activities would probably not be facilitated within the application area. On the other hand, concentration of predators to the general area may increase the probability of nest predation. BGR attracted nest predators in this study, but further research is required to evaluate its effect on predation of low nest densities within large application areas.

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5

EVALUATION OF SUITABILITY OF DEER-AWAY BIG GAME REPELLENT® FOR MANAGEMENT OF WATERFOWL NESTING HABITAT

5.1 EVALUATION CRITERIA

An ideal grazing management alternative for improving waterfowl production would protect nesting cover; be cost effective relative to other techniques; would offer management flexibility; and would not interrupt land use by restricting livestock access to resources. In addition, a grazing management tool designed to facilitate duck production would not avert waterfowl from using protected cover, nor would it increase the risk of predation. The suitability of Deer-Away Big Game Repellent® (BGR) for use in managing waterfowl nesting habitat should be evaluated on these criteria.

5.2 PROTECTION OF NESTING COVER

BGR reduced grazing by livestock during the season of application, thereby protecting and maintaining cover for nesting waterfowl. Furthermore, plant residues were allowed to accumulate where BGR was applied and spring growth increased in the subsequent season. These factors improved nesting conditions for waterfowl during the second year after initial application. Application of BGR successfully manipulated grazing to enhance nesting cover.

5.3 COST EFFECTIVENESS

The costs of using BGR to protect nesting habitat from grazing were compared to two wire alternatives in Appendix B. The wire fences were a permanent four strand barbed wire fence and a temporary single strand electrified fence. Relative costs among protection methods depend a great deal upon the size and shape of the application area. Large blocks of cover can be protected relatively cheaply with wire, particularly if perimeter fences already exist and only cross-fencing is required. However, if the entire perimeter of an area requires fencing, the costs per unit area increase substantially as the perimeter to area ratio increases (Table B.1). Costs of protection with BGR compare favorably with both fencing techniques on areas of 1 ha or less with small perimeter to area ratios. Protection with BGR is considerably more costly than fencing on larger areas with small perimeter to area ratios. BGR compares more favorably with fencing as the perimeter to area ratio of areas to be protected increases, particularly against the four strand barbed wire fence. The single strand electrified fence and BGR are similar in cost to protect areas with very large perimeter to area ratios.

Other factors should be considered when comparing BGR and fencing costs. The cost of a well built four strand barbed wire fence can be distributed over a large number of years, whereas BGR would require annual application. The single strand electrified fence was considered temporary, requiring erection and dismantling annually. However, the fencing materials are reusable, while BGR would need to be purchased every year. On the other hand, costs of additional watering facilities commonly required with fencing systems (Vallentine 1990) would not be necessary if grazing were managed with a repellent. Comparative costs of BGR relative to fencing methods will tend to be application specific, varying according to site characteristics and management objectives.

5.4 MANAGEMENT FLEXIBILITY

Probably the greatest advantage to using a repellent like BGR is its convenience. One person using an ATV-mounted sprayer could apply repellent quickly to large areas in almost any terrain. Areas to be protected can be chosen very selectively and can be rotated seasonally if desired without the need to construct fences. A seasonally applied repellent would allow quick responses to changing habitat requirements or management objectives. Strategies could be fine-tuned easily as information regarding nesting preferences within a management area increased over time. Once a barbed wire fence is erected, responses to subtle changes in management requirements would be limited. On the other hand, repellent applications might be used in conjunction with fencing to enhance protection of specific patches of habitat or to optimize benefits of the fencing system. Because repellent activity is not permanent, palatable reserves of strategically located winter forage could also be conserved for wild ungulates.

5.5 LAND USE INTERRUPTION

Repellent use eliminates the need for physical barriers to protect nesting cover from grazing. Livestock access to point resources such as water or minerals would therefore be unrestricted. This mobility negates the need for additional water developments, which is a matter of convenience in addition to cost. Furthermore, forage overutilization common near watering facilities (Vallentine 1989) could also be controlled with the repellent. Barriers to livestock movement can also be barriers to wildlife movement (Vallentine 1989). Kirby et al. (1992) cited a report by Coleman et al. (1990) of whooping crane mortality on a livestock fence. Barriers to wildlife mobility and risk of injury or death on fences would be reduced where nesting cover was protected with a grazing repellent. Where livestock grazing occurs on or near wildlife refuges, the absence of fences afforded by repellent use would add to aesthetic appeal as well.

5.6 WATERFOWL AVERSION

Failure of ducks to respond to the presence of BGR in this study indicated nesting waterfowl would not be averted from vegetation to which BGR was applied. However, this conclusion is uncertain until the role of olfaction in nesting behavior is better understood. Continued research studying waterfowl response to olfactory stimuli would enable testing of this assumption and may raise additional management implications.

5.7 NEST PREDATION

Concentration of nesting waterfowl on small patches of habitat increases the likelihood of nest predation (Sugden and Beyersbergen 1986, Environment Canada 1990). This problem applies to cover protected either by fencing or by repellent application.

However, BGR also provides an olfactory cue which may concentrate predator attention on the protected area. In practical applications, BGR would be applied to areas much larger than the plots used in this study. It is uncertain how a large odor field with no apparent point source would affect nest search success of mammalian predators, but attraction of predators to the general nesting area may reduce nest success via increased predation.

5.8 OTHER CONSIDERATIONS

Other considerations relevant to BGR use are its environmental impacts and selection of the appropriate formulation. In technical information acquired from the manufacturer, IntAgra Inc. claimed the repellent has very low toxicity to birds and mammals. Reported toxicity levels were as follows: acute oral LD_{50} for rats was 34,000 mg kg^{-1}; acute dermal LD_{50} for rabbits was 3000 mg kg^{-1}; and 8 day dietary LC_{50} for mallard ducks was 5000 ppm. IntAgra Inc. reported BGR was somewhat more toxic to fish. The four day static TL_{50} reported for rainbow trout was 504 ppm. The only phytotoxicity reported by IntAgra was slight browning of conifer needles and slowing of bud break.

The liquid formulation of BGR was more effective in reducing grazing and is probably more conducive to pasture application than the powder. Although the powder is in a ready to apply form, vegetation must be pre-moistened by rain, dew, or irrigation prior to application. The powder was difficult to apply evenly, which probably contributed to its lessor effectiveness. The powder was also irritating to skin and eyes. The liquid formulation required blending and dilution, but was not an irritant and was easy to apply once prepared. Either formulation has a shelf life in excess of one year, but prepared solutions of liquid begin to spoil after 24 hours.

5.9 CONCLUSIONS

BGR protected vegetation from herbivory, thereby demonstrating its potential for use in managing grazing for waterfowl production. BGR [illegible] ely benign environmentally and should not interfere with nest initiation. Major advantages of using BGR are its convenience and the absence of physical barriers to animal movement. Disadvantages include high cost relative to fencing methods for large areas of simple dimensions, and attraction of predators to areas protected with it. BGR's convenience must be weighed against its cost according to the circumstances of each management situation. However, specific effects on nest predation of BGR applied to large areas requires further investigation before its use in managing nesting cover is endorsed.

Other relevant research would include determining the role of olfaction (if any) on nest site selection, determining the longevity of BGR repellency towards ungulates, quantifying optimal application rates for pasture vegetation, and determining the optimum size of application area. Other potential repellents such as predator odors (Sullivan et al. 1985, Pfister et al. 1990), animal manures (Marten 1978), and plant secondary compounds (Müller-Schwarze 1991) exist which may be more favorable than BGR. These products should also be evaluated.

As human demands for land resources increase, continued innovation in land management will be required to reduce conflicts between human and faunal land users. BGR was useful in demonstrating livestock grazing can be managed chemically with repellents. However, because of potentially increased predation risks, BGR may not be ideal for managing grazing within waterfowl nesting habitats.

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APPENDIX A

VEGETATION COMPOSITION

AND PHYTOMASS EQUIVALENCE OF

CANOPY MEASUREMENTS

A.1. VEGETATION COMPOSITION

Composition of vegetation within treatment plots was estimated in June of 1991. Relative composition of species was estimated according to Wroe et al. (1988) within five 20 x 50 cm quadrats (Daubenmire 1959) placed systematically within treatment plots. Relative area of ground covered by bare soil, green vegetation (area of ground occupied by live plants at the soil interface), and litter was estimated within the same quadrats. Primary species recorded included *Bromus inermis* Leyss., *Festuca rubra* L., *Dactylis glomerata* L., *Phleum pratense* L., *Trifolium hybridum* L., *Calamagrostis canadensis* Michx., and *Alopecurus pratensis* L. Other species such as weeds and native forbs and shrubs were also recorded. Individuals of these species never exceeded 2% of total composition within plots and were therefore pooled for comparisons. Species composition and ground cover comparisons among repellent treatments are summarized in Tables A.1 and A.2. Comparisons among landscape positions are summarized in Tables A.3 and A.4.

Table A.1. Composition of vegetation among Big Game Repellent® treatments.

	Treatment			
Species	Control	Powder	Liquid	SEM
	(%)			
Bromus inermis Leyss.	17.4[a]	17.9[a]	19.2[a]	1.22
Phleum pratense L.	11.8[a]	10.9[a]	15.3[b]	1.16
Dactylis glomerata L.	18.3[a]	21.0[a]	19.1[a]	1.30
Alopecurus pratensis L.	9.9[a]	10.2[a]	8.1[a]	1.07
Calamagrostis canadensis Michx.	2.3[a]	0.9[a]	0.8[a]	0.99
Festuca rubra L.	16.2[a]	15.8[a]	17.1[a]	0.92
Trifolium hybridum L.	16.6[a]	15.1[a]	14.3[a]	1.66
Other	7.4[a]	8.2[a]	6.1[a]	0.82

Values within species followed by the same superscript do not differ ($P<0.05$); n = 16.

Table A.2. Ground coverage among Big Game Repellent® treatments.

	Treatment			
Ground Cover	Control	Powder	Liquid	SEM
	(%)			
Bare Soil	7.2^{a}	7.8^{a}	6.7^{a}	1.05
Green Vegetation	60.9^{a}	60.9^{a}	61.3^{a}	3.31
Litter	31.9^{a}	31.3^{a}	32.0^{a}	3.20

Means within cover categories followed by the same superscript do not differ ($P > 0.05$); n = 16.

Table A.3. Composition of vegetation among landscape positions.

	Landscape Position				
Species	Hilltops	Low Lands	North Slopes	South Slopes	SEM
	(%)				
Bromus inermis Leyss.	25.1^{c}	6.3^{a}	17.1^{b}	23.4^{c}	1.41
Phleum pratense L.	10.4^{a}	14.6^{b}	16.0^{b}	9.7^{a}	1.34
Dactylis glomerata L.	18.2^{b}	9.1^{a}	23.0^{c}	27.6^{d}	1.50
Alopecurus pratensis L.	7.9^{b}	20.0^{c}	7.2^{b}	2.5^{a}	1.24
Calamagrostis canadensis Michx.	0.0^{a}	5.25^{b}	0.0^{a}	0.0^{a}	1.15
Festuca rubra L.	20.2^{b}	12.7^{a}	20.0^{b}	12.6^{a}	1.07
Trifolium hybridum L.	14.1^{ab}	14.8^{ab}	13.2^{a}	19.2^{b}	1.92
Other	3.2^{a}	17.2^{b}	3.5^{a}	5.0^{a}	0.95

Values within species followed by the same superscript do not differ ($P > 0.05$); n = 12.

Table A.4. Ground coverage among landscape positions.

	Landscape Position				
Ground Cover	Hilltops	Lowlands	North Slopes	South Slopes	SEM
	(%)				--
Bare Soil	3.4^{a}	3.3^{a}	2.1^{a}	20.0^{b}	
Green Vegetation	59.4^{ab}	71.7^{c}	63.3^{bc}	50.0^{a}	3.83
Litter	37.2^{b}	25.0^{a}	34.6^{b}	30.0^{ab}	3.69

Values within cover categories followed by the same superscript do not differ ($P < 0.05$); n = 12.

A.2. PHYTOMASS/CANOPY MEASUREMENT RELATIONSHIPS

Linear relationships between canopy measurements and phytomass were determined by clipping and weighing vegetation supporting the polystyrene measuring board. A 61 x 61 cm (inside measurement) frame was constructed from 1 cm square steel bar. The frame was laid horizontally on the soil surface at 15 locations within each treatment block, encompassing the range of canopy heights there. Vegetation within the frame was clipped to a height of 1 cm after the canopy was measured. All standing vegetation, including current growth and weathered material from the previous season, was collected. Clipping was done during 10 to 12 July. Clipped vegetation was oven dried at 60° C for 48 hours and then weighed. Regressions of phytomass on canopy measurements are illustrated in Fig. A.1. Relationships were only described for landscape positions because vegetation species and ground cover were similar among repellent treatment plots.

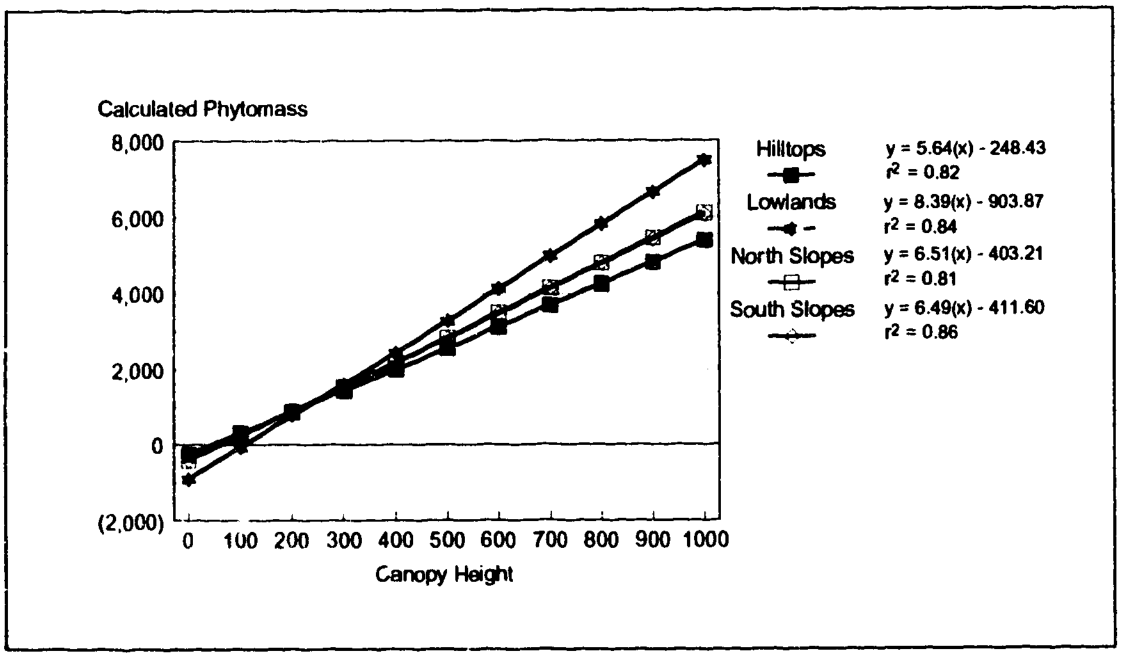

Fig. A.1. Regression of phytomass on canopy heights within landscape positions.

A.3. LITERATURE CITED

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Wroe, R.A., S. Smoliak, B.W. Adams, W.D. Willms, and M.L. Anderson. 1988. Guide to range condition and stocking rates for Alberta grasslands. Alberta Forestry, Lands and Wildlife.

APPENDIX B

COST COMPARISON OF DEER-AWAY BIG GAME REPELLENT®

AND WIRE FENCING

B.1. ASSUMPTIONS

B.1.1 Big Game Repellent® (BGR) Application Rate

An optimal application rate has not been determined for BGR. Rates will vary with the height and density of vegetation to which it is applied, but BGR is likely to be effective at application rates lower than was used in this study. Patent documents suggested rates between 20 and 100 L ha^{-1} for application to 2-3 year old tree seedlings at a density of 600-700 seedlings ha^{-1}. A rate of 100 L ha^{-1} of BGR solution prepared according to label directions was used for calculation of BGR material costs. The unit price for active ingredient in the powder formulation is the same as for liquid. Therefore, costs per hectare will be similar regardless of BGR formulation. Prices were obtained from Margo Supplies Ltd., Site 20, Box 11, R. R. 6, Calgary, Alberta, T2M 4L5. Margo Suppiies is a distributor of wildlife control products and a fencing contractor.

B.1.2 Fencing Material Costs

Required fencing materials were calculated for fencing the perimeter of an area equal to the area protected with BGR.

i) *Permanent four strand barbed wire:*

Material costs were obtained from the Engineering Field Services Branch of Alberta Agriculture. Costs were based on building a standard four strand barbed wire fence with wooden posts spaced 16 feet apart.

ii) *Temporary single strand electrified:*

Material costs were obtained from Margo Supplies Ltd. Costs were based on building a single strand electrified fence using high visibility polymer tape attached to five foot fiberglass posts with spin-on insulators, spaced 40 feet apart.

B.1.3 Labor costs:

i) *BGR:*

Application labor costs were calculated using custom rates for herbicide application published by the Farm Business Management Branch of Alberta Agriculture.

ii) *Permanent Four Strand Barbed Wire:*

Labor costs were calculated using custom rates for fencing published by the Farm Business Management Branch of Alberta Agriculture.

iii) *Temporary Single Strand Electrified Fence:*

Labor required to erect this fence was estimated by Jeff Marley of Margo Supplies Ltd. to be one fifth of the requirement for the standard four strand barbed wire fence. This estimate was doubled to reflect removal, as well as construction of the fence.

B.2. COST CALCULATIONS

B.2.1 Big Game Repellent®

Repellent: 100 L ha^{-1} x \$4.62 L^{-1}	=	\$ 462 ha^{-1}
Custom Application Rate	=	\$ 8 ha^{-1}
Total	=	\$ 470 ha^{-1}

B.2.2 Four Strand Barbed Wire Fence:

Materials	=	\$ 1250 km^{-1}
Labor	=	\$ 875 km^{-1}
Total	=	\$ 2125 km^{-1}

B.2.3 Single Strand Electrified Fence:

Materials	=	\$ 320 km^{-1}
Labor (\$875 x 0.40)	=	\$ 350 km^{-1}
Total	=	\$ 670 km^{-1}
Energizer and Battery	=	\$ 200 km^{-1}

Note: Single energizer is sufficient to power 3-4 km of fence.

B.3 COST SUMMARY

Costs associated with BGR application vary directly with the area of the site to be protected, regardless of its shape. Fencing costs vary with the length of perimeter to be fenced. Therefore, fencing costs per unit area vary considerably with the perimeter to area ratio of the site to be protected. Sites with high perimeter to area ratios are more costly to fence than sites with low perimeter to area ratios. This is illustrated in Table B.1.

Table B.1. Examples of application costs of Big Game Repellent® in comparison to two fencing techniques for protecting sites with equal perimeters but different dimensions.

Perimeter (m)	Dimensions (m)	Area Protected (ha)	Total Cost: Big Game Repellent®	Total Cost: 4 Strand Barbed Wire	Total Cost: 1 Strand Electrified[1]
400	100 x 100	1.0	$470.00	$850.00	$468.00
	50 x 150	0.75	$352.50	$850.00	$468.00
800	200 x 200	4.0	$1880.00	$1700.00	$736.00
	50 x 350	1.75	$822.50	$1700.00	$736.00
1600	400 x 400	16.0	$7520.00	$3400.00	$1272.00
	50 x 750	3.75	$1762.00	$3400.00	$1272.00

[1]Costs based on linear materials and labor requirements plus one energizer and battery. One energizer is sufficient to power 3 - 4 km linear distance.

B.4 RELEVANT LITERATURE

Alberta Agriculture. 1987. Wetaskiwin fence demonstration project. Engineering Field Services Branch. D230E/081586/NI.

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Oita, K., M.R. San Clemente, J.H. Oh, and G.T. Tiedeman. 1977. Method for using a ruminant repellent comprising oxidation precursors of aliphatic aldehydes. U.S. Patent Doc. No. 4,065,576.

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APPENDIX C

CHEMICAL ANALYSIS OF DEER-AWAY BIG GAME REPELLENT®

C.1. OBJECTIVE

Label information and patent documentation for Deer-Away Big Game Repellent® (BGR) claimed the product would provide protection from deer browsing for up to 2 months. However, the manufacturer was unaware of any data which confirmed the degradation time of the repellent once applied to vegetation (Marty Proops, Specialty Products Manager, IntAgra Inc., pers. comm.). Therefore, the duration of repellent detectability on vegetation was explored.

C.2. METHODS

Components of BGR likely to be repellent to ruminants were determined from review of patent documents and other literature. Based on the information collected, an attempt was made to isolate these compounds from samples of BGR using gas chromatographic-mass spectrometric (GC-MS) techniques. Meanwhile, samples of vegetation to which BGR was applied were collected over time. These were similarly analyzed to determine the duration of repellent detectability.

Product information from the manufacturer indicated BGR contained putrescent whole egg solids suspended in oil and had a slight fermented egg odor. Patent documentation stated the repellent was derived from fresh lipoidal material of a dried egg source. Also, aliphatic aldehydes and their oxidation precursors may have been added to fortify the repellency of the lipoidal material. One of several latex binders are used to help the repellent adhere to vegetation and resist weathering.

Laboratory analysis was contracted to Laboratory Services, Department of Animal Science, University of Alberta. Because lipids were prevalent, techniques described by Ajuyah et al. (1993) were followed to isolate their volatile components. Head space volatiles were collected by applying vacuum to flasks containing 20 g samples of prepared BGR solution and trapping the volatiles on a Tenax-GC trap overnight. The volatiles were extracted from the trap with hexane and methanol. The extract solution was then concentrated for injection on the GC-MS.

Oxidation products were generated by passing air through mixtures of BGR concentrate and water while heating and stirring. Organics were collected on a Sep-Pak C18 cartridge and extracted with hexane for injection on the GC-MS.

Head space volatiles of vegetation samples were analyzed in the manner described for BGR samples. Less volatile components were collected by vacuum distillation followed by trapping on a Sep-Pak cartridge. Volatiles were extracted from the cartridge with pentane for injection on the GC-MS.

All analyses were conducted on a Hewlett Packard Model 5890 Series II. The detector was an HP 5971A Mass Selective Detector operated in Scan Mode. The detector used an impact ion source with a 70 eV ionizing potential. The column used was a J & W Scientific DB5-MS, 30 m x 0.25 mm ID x 0.25 micron film. The temperature program for analyses other than those conducted according to Ajuyah et al. (1993) was as follows: 60° C initial temperature held for 2 minutes, rising to 120° C at 10° C min^{-1}; then rising to 270° C at 30° C min^{-1}. The final temperature was held for 5 minutes.

C.3. RESULTS

BGR contained a free fatty acid composition typical of egg lipids (see Ajuyah et al. 1993). Several long chain hydrocarbons were also detected, which probably came from the oil used by the manufacturer to suspend the egg solids. Organo-sulfides and alkyl benzenes similar to those found in fermented egg by Bullard et al. (1978) were detected in the head space. However, none of the volatile fatty acids described by Bullard and associates were detected among the lipid components. No aldehydes or oxidation precursors were detected.

Several aldehydes were detected in vegetation samples but chromatograms were not reproducible, presumably due to instability of the aldehydes. None of the other potentially repellent compounds were detectable on vegetation samples and further analysis was abandoned.

C.4. CONCLUSION

The analysis of BGR was unsuccessful in determining the degradation time of BGR applied to vegetation. Why repellent compounds were not detectable on vegetation samples is unknown. The duration of repellent detectability on vegetation might be determined more readily using grazing animals. Pasture plots treated with BGR could be grazed sequentially with increasing intervals between repellent application and grazing. Consumption would then be compared between treated and untreated plots.

This analysis was able to confirm that BGR contained lipids from a fresh egg source. Because no volatile fatty acids were detected, little fermentation or putrefaction of the lipoidal material took place during the manufacturing process.

C.5 RELEVANT LITERATURE

Ajuyah, A.O., T. Fenton, and J.S. Sim. 1993. Measuring lipid oxidation volatiles in meats. J. Food Sci. in press.

Bullard, R.W., T.J. Leiker, J.E. Peterson, and S.R. Kilburn. 1978. Volatile components of fermented egg, an animal attractant and repellent. J. Agric. Food Chem. 26:155-159.

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